

What is claimed is:

[Claim 1] A method for detecting metal extrusion associated with electromigration (EM) under high current density situations within an EM test line, the method comprising the steps of:

situating one end of an electrically conductive lead close to a single anticipated location of metal extrusion associated with electromigration on the EM test line, such that the end of the electrically conductive lead in combination with the single anticipated location of metal extrusion together comprise two charge storing surfaces of a single capacitor having an electrical capacitance; measuring the capacitance of the single capacitor prior to operation of the EM test line;

making subsequent measurements of the capacitance of the single capacitor during or after operation of the EM test line; and

detecting changes in the capacitance of the said single capacitor to detect metal extrusion associated with electromigration.

[Claim 2] The method of Claim 1 further comprising the steps of:

situating one or more additional ends of one or more additional electrically conductive leads close to the single anticipated location of metal extrusion associated with electromigration on the EM test line, such that the end of each additional electrically conductive leads in combination with the single anticipated location of metal extrusion comprise charge storing surfaces of one or more additional capacitors each having an electrical capacitance; measuring the capacitance of the single capacitor and the capacitances of the one or more additional capacitors prior to operation of the EM test line; making subsequent measurements of the capacitance of the single capacitor and the capacitances of the one or more additional capacitors during or after operation of the EM test line; and

detecting changes in the capacitance of the single capacitor and the capacitances of the one or more additional capacitors to detect metal extrusion associated with electromigration.

[Claim 3] The method of Claim 2 further including the step of: connecting the single capacitor and the one or more additional capacitors in parallel.

[Claim 4] The method of Claim 1 further including the steps of: situating one or more additional ends of each of one or more additional electrically conductive leads close to one or more additional possible locations of metal extrusion associated with electromigration on the EM test line, such that each end of each electrically conductive lead in combination with each additional possible location of metal extrusion together comprise charge storing surfaces of one or more additional capacitors each having an electrical capacitance; measuring the capacitance of the single capacitor and the capacitances of each of the one or more additional capacitors prior to operation of the EM test line; making subsequent measurements of the capacitance of the single capacitor and the capacitances of the one or more additional capacitors during or after operation of the EM test line; and detecting changes in the capacitance of the single capacitor and the capacitances of the one or more additional capacitors to detect metal extrusion associated with electromigration.

[Claim 5] The method of Claim 4 further including the step of connecting the single capacitor and the one or more additional capacitors in parallel to comprise a module.

[Claim 6] A method for detecting metal extrusion associated with electromigration (EM) under high current density situations within two or more EM test lines within a circuit, the method being characterized by the steps of: situating the ends of one or more electrically conductive leads close to one or more anticipated locations of metal extrusion associated with electromigration on one of the two or more EM test lines, such that each end of each electrically conductive lead in combination with each of the one or more anticipated locations of metal extrusion on each of the two or more EM test lines together comprise two charge storing surfaces of one or more capacitors each having an electrical capacitance; measuring the capacitance of each of the one or more capacitors prior to operation of the EM test lines; making subsequent measurements of the capacitance of each of the one or more capacitors during or after operation of the EM test lines; and detecting changes in the capacitance of each of the one or more capacitors to detect metal extrusion associated with electromigration.

[Claim 7] The method of Claim 6 further including the steps of: connecting the one or more capacitors comprised of ends of one or more electrically conductive leads close to one or more single anticipated locations of metal extrusion on each of the two or more EM test lines in parallel to create a capacitive extrusion monitor module for each EM test line; measuring the capacitance of each module on each of the two or more EM test lines prior to operation; making subsequent measurements of the capacitance of each module during or after operation of the EM test line; and detecting changes in the capacitance of each module to detect metal extrusion associated with electromigration.

[Claim 8] The method of Claim 7 further including the steps of;

connecting in parallel two or more of each of the capacitive extrusion monitor modules of each of the two or more EM test lines within the circuit to create one or more capacitive extrusion monitor meta-modules;
measuring the capacitance of each meta-module prior to operation;
making subsequent measurements of the capacitance of each meta-module during or after operation; and
detecting changes in the capacitance of each meta-module to detect metal extrusion associated with electromigration.

[Claim 9] The method of Claim 8 further including the steps of: connecting in parallel two or more of each of the capacitive extrusion monitor meta-modules; and
equipping all of the two or more capacitive extrusion monitor meta-modules with a decoder to determine the meta-module in which metal extrusion has occurred.

[Claim 10] The method of Claim 9 further including the step of incorporating in close proximity with each of the two or more EM test lines within the circuit one or more leakage current type extrusion monitors.

[Claim 11] An apparatus for monitoring and detecting metal extrusion associated with electromigration (EM) under high current density situations within EM test lines within a test circuit, the apparatus comprising:
capacitive means for detecting metal extrusion.

[Claim 12] The apparatus of Claim 11 wherein the capacitive means comprises an end of an electrically conductive lead disposed in close proximity to an anticipated site of metal extrusion on an EM test line such that the combination of the anticipated site and the end of the electrically conductive lead comprise two charge storing surfaces of a capacitor having a capacitance

that changes when a metal extrusion at the anticipated site influences the geometry and the capacitance of said capacitor.

[Claim 13] The apparatus of Claim 11 wherein the capacitive means comprises an end of a plurality of electrically conductive leads each disposed in close proximity to an anticipated site of metal extrusion on an EM test line such that the combination of the anticipated site and each of the ends of each of the plurality of electrically conductive leads comprise charge storing surfaces of one or more capacitors each having a capacitance that changes when a metal extrusion at the anticipated site influences the geometry and the capacitances of the one or more of the capacitors.

[Claim 14] The apparatus of Claim 11 wherein the capacitive means comprises an end of each of a plurality of electrically conductive leads each disposed in close proximity to at least two anticipated sites of metal extrusion on an EM test line such that the combination of each anticipated site and the ends of the electrically conductive leads in close proximity thereto comprise charge storing surfaces of one or more capacitors each having a capacitance that changes when a metal extrusion at the at least one of the at least two anticipated sites influences the geometry and the capacitance of the one or more of the capacitors.

[Claim 15] The apparatus of Claim 13 wherein the one or more of the capacitors that are comprised of charge storing surfaces of the ends of each of the more than one electrically conductive leads are connected in parallel to create a module.

[Claim 16] The apparatus of Claim 11 wherein the capacitive means comprises one end of each of the more than one electrically conductive leads each disposed in close proximity to at least one anticipated site of metal extrusion on each of at least two EM test lines such that the combination of

each anticipated site on each of the at least two EM test lines and the ends of the electrically conductive leads in close proximity thereto comprise charge storing surfaces of one or more of the capacitors each having a capacitance that changes when a metal extrusion at the at least one of the anticipated sites on the at least two EM test lines influences the geometry and the capacitance of the one or more of the capacitors.

[Claim 17] The apparatus of Claim 16 wherein the capacitors comprised of charge storing surfaces of the ends of each of the more than one electrically conductive leads disposed in close proximity to one or more of each of at least one anticipated site on each of the at least two EM test lines are connected in parallel to create one or more modules of parallel connected capacitors for each of the at least two EM test lines.

[Claim 18] The apparatus of Claim 17 wherein each of the one or more modules of parallel connected capacitors for each of the at least two EM test lines are parallel connected to create at least one or more meta-modules of parallel connected modules for each set of one or more EM test lines.

[Claim 19] The apparatus of Claim 18 wherein two or more of each of the capacitive extrusion monitor meta-modules are connected in parallel and equipped with a decoder to determine the meta-module in which metal extrusion has occurred.

[Claim 20] The apparatus of Claim 19 wherein one or more of the EM test lines is further monitored for metal extrusion by the use of one or more standard leakage current type extrusion monitors.